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Compaction as Affected by Bulk Density and Dry Density of a Soil

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Abstract:
The study, compaction as affected by bulk density and dry density of a soil in Maiduguri has been evaluated and achieved. Appropriate techniques were employed to find the moisture content, depth, particle size, dry density and bulk density in order to determine their effects on soil compaction collected at ten (10) different locations: Ramat Poly, Bololri, Limanti, Gamboru, Shehuri North, Gwange, Bulabulin, Polo Ground, National Stadium and Teachers Village.respectively and at different depths; 0.5m, 1.0m, 1.5m, 2.0m. A graph of Dry Density vs Moisture Content obtained from Standard Proctor Compaction Test for the ten (10) locations have been drawn showing, the Maximum Dry Density (MDD) and the corresponding Optimum Moisture Content (OMC) under each compaction. The values of MDD and OMC were indicated on each graph. The curves with the peaks shown in Figures 4.3 - 4.12 are known as the 'moisture-content dry density curves' or the 'compaction curves'. The state at the peaks are said to be that of 100% compaction at the particular compactive effort. The curves obtained were hyperbolic form, because the points obtained from the tests were smoothly joined. The texture of soil depends on the relative size and shape of the particles as well the range or distribution of those sizes. The evaluated values obtained in this study were presented so as to assist in research fields of study such as soil science, geotechnical related issues and engineering, agriculture and water resources as the case may be in those study areas.

***Key Word**: Soil; Compaction; Bulk Density; Dry Density; Moisture.*

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I. Introduction

Compaction of soil is the process by which the solid particles are packed more closely together, usually by mechanical means, thereby increasing the bulk and dry density of the soil and reducing the porosity of the soil [1,2]. It is has been considered to be a multi-disciplinary problem in which machine, soil, crop, and weather interactions play an important role. Soil compaction is a concern to many soil scientists, Agricultural Engineers and farmers, as it may have serious economic and environmental consequences in the world agriculture. Soil bulk density defines as the weight of elastic and other solid material per unit volume of soil. The value of soil bulk density ranged between 1.0 $g\ cm^{-3}$ to 2.65 $g\ cm^{-3}$. A compacted soil achieves bulk density in excess of 2.3 $g\ cm^{-3}$. Depend on some factors affecting soil bulk density, most mineral soil value ranged between 1.1 $g\ cm^{-3}$ and 1.6 $g\ cm^{-3}$ [3,4]. The scope for soil compaction engineering is going to increase with the increase of activity in various fields. Thus, careful study of present methods is necessary and improvements should be made over conventional methods wherever possible to get immediate results without affecting the accuracy. In order to overcome the large time and effort of carrying out standard Proctor's test an attempt has been made to obtain compaction characteristic using static compaction method for obtaining the compaction characteristics of the soil equivalent to Proctor's test in the laboratory [5].

The behavior of every foundation, roads, airfields etc depends primarily on the engineering characteristics of the underlying deposits of soil or rock. The proper compaction of the soil is intended to ensure that the compacted soil will reliably and safely withstand loads of various kinds. Soil compaction on construction sites occurs either deliberately when foundations and sub grades are prepared or as an unintended result of vehicular traffic [6]. Soil compaction decreases porosity [7]. To determine whether a soil is compacted or not, and thus whether a treatment is necessary for the alleviation of soil compaction, the degree of compaction needs to be quantified.

It has been said that the top three factors in real estate are "location, location and location". It can also be said that the top three factors in road pavement construction are "compaction, compaction, and compaction".

Compaction is the process by which the volume of air in a pavement mixture is reduced by using external forces to reorient the constituent aggregate particles into a more closely spaced arrangement. This reduction of air volume in a mixture produces a corresponding increase in unit weight or density [8]. Numerous researchers have stated that compaction is the greatest determining factor in dense graded pavement performance [9-15]. Among the major causes for failure of roads in the tropics is inadequate compaction during construction. There is, therefore, the need to strictly control the compaction of the pavement layers if the design life of the road is to be attained; thereby eliminating large maintenance costs.

II. Material And Methods

Sample collection at different points, locations and preparation: Ten different locations in Maiduguri namely; Ramat Polytechnic, Bolori Ward, Shehuri North, Limanti Ward Gwange Ward, Gamburu Ward, Bulabulin Ward, Polo Ground, National Stadium and Teachers Village, were randomly identified and marked for sample collection. The top surface soil was cleared using shovel in order to properly drill the soil auger into the soil. The length of the soil auger is 2 *m* long, but, it is detachable and can be screwed at every 1 *m* point length. The soil auger was marked at every 0.5 *m*, 1.0 *m*, 1.5 *m* and 2.0 *m*, which respectively corresponds to a depth of 0.5 *m*, 1.0 *m*, 1.5 *m* and 2.0 *m* drilled into the soil.

At every marked point on the soil auger, the soil samples were collected into a container of known mass. The combined mass of sample and container were weighed using electronic balance and be recorded. More samples were collected and put into polythene bags in order to preserve their water contents. The process was repeated for the other depths e.g. 1.0 *m*, 1.5 *m* and 2.0 *m*, for all the locations. Finally, the soil samples were taken to the Civil Engineering Laboratory, Ramat Polytechnic, Maiduguri, for further analysis.

Determination of bulk density: About 4 *kg* of the dried soil sample from Ramat Polytechnic Maiduguri at 0.5 *m* depth was weighed using balance and the sample was transferred in a pan. 3%, 6%, 9% and 12% of water; that is 120 *ml*, 240 *ml*, 360 *ml* and 480 *ml* of water were measured using graduated measuring cylinder. The different percentages of water were one after the other poured into the pan containing the soil sample and mixed using spoon. The mixture was put into a cylindrical mold of known mass for compaction. At every percentage of water added to the soil in the mould, the mixture was given twenty five (25) blow counts until the mold was completely filled up by compaction. The mould and its content were recorded. Next, the process was repeated for 6%, 9% and 12% until a maximum dry density was attained. That is, further increase in the percentage or value of water, the mixture gave a value of the mass less than the just previous one (reading), that is the weight volume of the sample. The process was repeated for the other locations, namely; Bolori Ward, Shehuri North, Limanti Ward Gwange Ward, Gamburu Ward, Bulabulin Ward, Polo Ground, National Stadium and Teachers Village. The value of the bulk density was obtained by dividing the mass of soil under each percentage of water added with the volume of the mould. The practical was performed in the Analytical Civil Engineering Laboratory, Ramat Polytechnic Maiduguri, using Standard Proctor Compaction Test Method. B.S.1377 [16]. The Bulk Density of the samples are calculated from the formula:

$$\text{Bulk Density} = \frac{Mass\ of Mold}{Volume\ \ of Mold} \quad (1)$$

Equation (1) will be used to calculate the bulk density of the soil sample.

Determination of dry density: Determination of dry density was performed simultaneously with bulk density under the same experimental procedure of compaction that was carried out in determining bulk density. The value of the dry density was evaluated by simple calculation of data obtained in the determination of bulk density. That is, the value of the bulk density obtained from the compaction test divided by the sum of 1 plus moisture content. The method that was used is the Standard Proctor Compaction Test. B.S.1377 [17].
The dry density of the soil sample is calculated from the formula below:

$$\text{Dry density} = \frac{\text{bulk density}}{1+\text{moisture content}} \quad (2)$$

Equation (2) will be used to calculate dry density of the soil sample.

III. Result

Tables 1 – 10 showed the Results obtained from Standard Proctor Compaction Test at Ramat Polytechnic, Bolori, Limanti, Gamboru, Shehuri North, Gwange, Bulabulin, Polo Ground, National Stadium and Teachers Village respectively for wet (bulk) density, dry density, and moisture content under each percentage adding of water and compaction.

Table 1: Result obtained from Proctor Compaction Test at Ramat Polytechnic

M_{AS} %	W_M (g)	W_{MS} (g)	W_S (g)	ρ_B(g/cm^3)	ρ_D(g/cm^3)	CN	W_C (g)	W_{SC} (g)	W_{DC} (g)	W_D (g)	W_W(g)	W %
3	1851	3900	2049	2.11	2.02	A1	20.00	49.40	48.10	28.10	1.30	4.60
6	1851	4100	2249	2.32	2.05	A2	19.90	56.80	54.30	34.40	2.50	7.30
9	1851	4200	2349	2.42	2.09	A3	25.20	59.60	55.40	30.20	4.20	13.90
12	1851	4100	2249	2.32	2.01	A4	23.10	55.30	51.30	28.20	4.00	14.20

Keys: M_{AS} % = moisture edition soil; W_M (*g*) = weight of mold; W_{MS} (*g*) = weight of mold + weight of soil; W_S (*g*) = weight of wet soil; ρ_B (*g/cm*^{3}) = bulk density; ρ_D (*g/cm*^{3}) = dry density; CN = container number; W_C (*g*) = weight of container; W_{SC} (*g*) = weight of wet soil + container; W_{DC} (*g*) = weight of dry soil + container; W_D (*g*) = wet of dry soil; W_W (*g*) = weight of water; W % = moisture content.

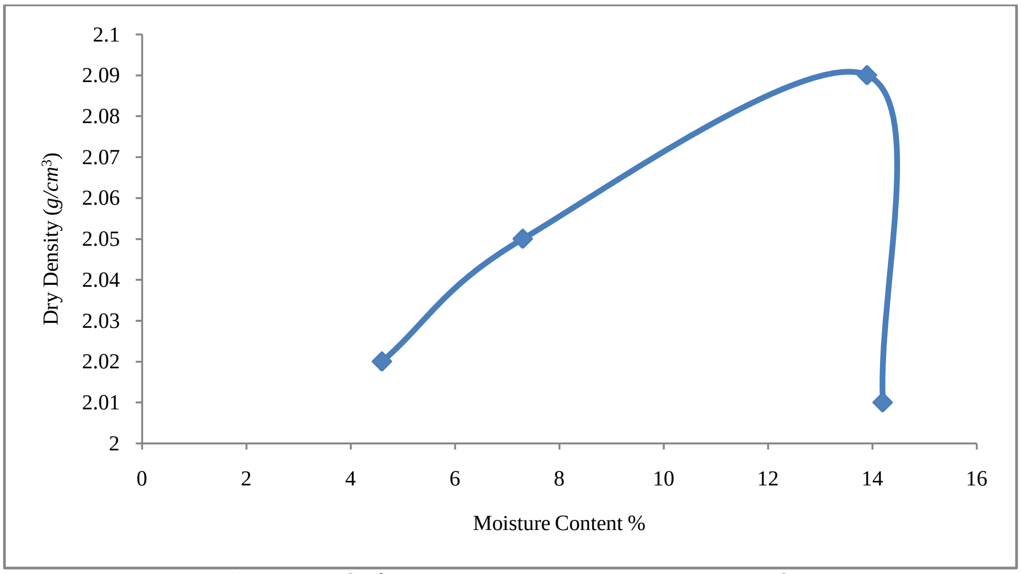

Figure 1: Graph of Dry Density vs Moisture Content at Ramat Poly.

Table 2: Result obtained from Proctor Compaction Test at Bolori

M_{AS} %	W_M (g)	W_{MS} (g)	W_S (g)	ρ_B(g/cm^3)	ρ_D(g/cm^3)	CN	W_C (g)	W_{SC} (g)	W_{DC} (g)	W_D (g)	W_W (g)	W %
3	1851	3900	2049	2.11	2.04	B1	11.0	50.3	49.0	38.0	1.3	3.40
6	1851	4000	2149	2.22	2.07	B2	11.6	43.2	41.2	29.6	2.0	6.76
9	1851	4100	2249	2.32	2.10	B3	10.6	44.6	41.4	30.8	3.2	10.39
12	1851	3900	2049	2.11	1.86	B4	11.0	43.4	39.6	28.6	3.8	13.29

Keys: M_{AS} % = moisture edition soil; W_M (*g*) = weight of mold; W_{MS} (*g*) = weight of mold + weight of soil; W_S (*g*) = weight of wet soil; ρ_B (*g/cm*^{3}) = bulk density; ρ_D (*g/cm*^{3}) = dry density; CN = container number; W_C (*g*) = weight of container; W_{SC} (*g*) = weight of wet soil + container; W_{DC} (*g*) = weight of dry soil + container; W_D (*g*) = wet of dry soil; W_W (*g*) = weight of water; W % = moisture content.

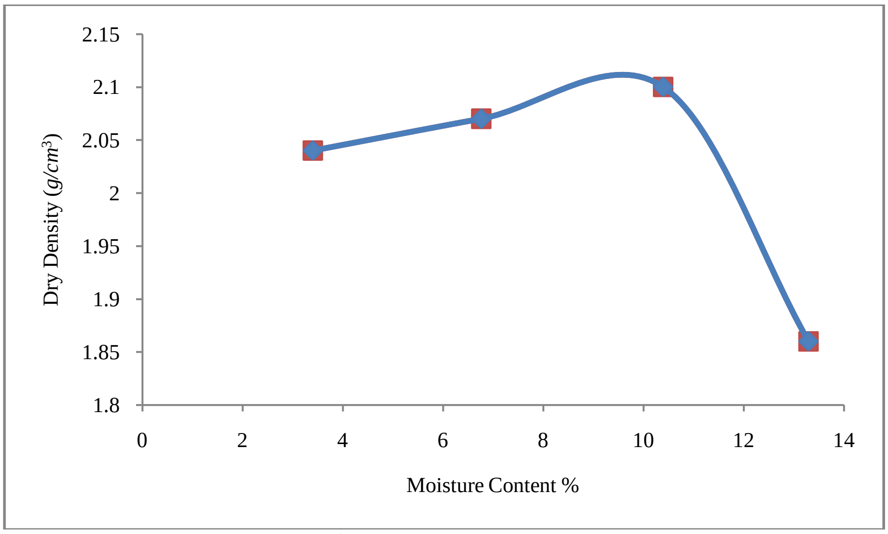

Figure 2: Graph of Dry Density vs Moisture Content at Bolori

Table 3: Result obtained from Proctor Compaction Test at Limanti

M_{AS} %	W_M (g)	W_{MS} (g)	W_S (g)	ρ_B (g/cm^3)	ρ_D(g/cm^3)	CN	W_C (g)	W_{SC} (g)	W_{DC} (g)	W_D (g)	W_W (g)	W %
3	1851	3900	2049	2.11	2.04	C1	11.5	38.5	37.6	26.1	0.90	3.45
6	1851	4000	2149	2.22	2.07	C2	11.5	48.6	46.1	34.6	2.50	7.23
9	1851	4100	2249	2.32	2.10	C3	10.9	50.0	46.3	35.4	3.70	10.45
12	1851	4000	2149	2.22	1.96	C4	11.3	50.4	45.9	34.6	4.50	13.01

Keys: M_{AS} % = moisture edition soil; W_M (*g*) = weight of mold; W_{MS} (*g*) = weight of mold + weight of soil; W_S (*g*) = weight of wet soil; ρ_B (*g/cm*^{3}) = bulk density; ρ_D (*g/cm*^{3}) = dry density; CN = container number; W_C (*g*) = weight of container; W_{SC} (*g*) = weight of wet soil + container; W_{DC} (*g*) = weight of dry soil + container; W_D (*g*) = wet of dry soil; W_W (*g*) = weight of water; W % = moisture content.

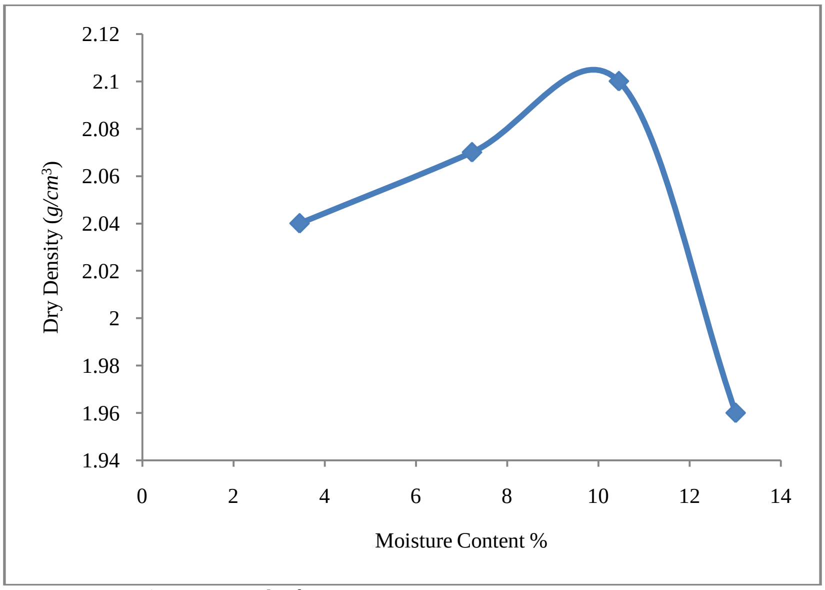

Figure 3: Graph of Dry Density vs Moisture Content at Limanti.

Table 4: Result obtained from Proctor Compaction Test at Gamboru

M_{AS} %	W_M (g)	W_{MS}(g)	W_S (g)	ρ_B(g/cm^3)	ρ_D(g/cm^3)	CN	W_C (g)	W_{SC} (g)	W_{DC} (g)	W_D (g)	W_W (g)	W %
3	1851	3700	1849	1.91	1.85	D1	11.5	52.8	51.5	41.0	1.3	3.17
6	1851	3900	2049	2.11	1.97	D2	11.0	55.4	52.5	41.5	2.9	6.99
9	1851	4000	2149	2.20	2.00	D3	10.9	57.9	53.6	42.7	4.3	10.00
12	1851	3800	1949	2.01	1.74	D4	11.8	61.6	54.9	43.1	6.7	15.50

Keys: M_{AS} % = moisture edition soil; W_M (*g*) = weight of mold; W_{MS} (*g*) = weight of mold + weight of soil; W_S (*g*) = weight of wet soil; ρ_B (*g/cm*^{3}) = bulk density; ρ_D (*g/cm*^{3}) = dry density; CN = container number; W_C (*g*) = weight of container; W_{SC} (*g*) = weight of wet soil + container; W_{DC} (*g*) = weight of dry soil + container; W_D (*g*) = wet of dry soil; W_W (*g*) = weight of water; W % = moisture content.

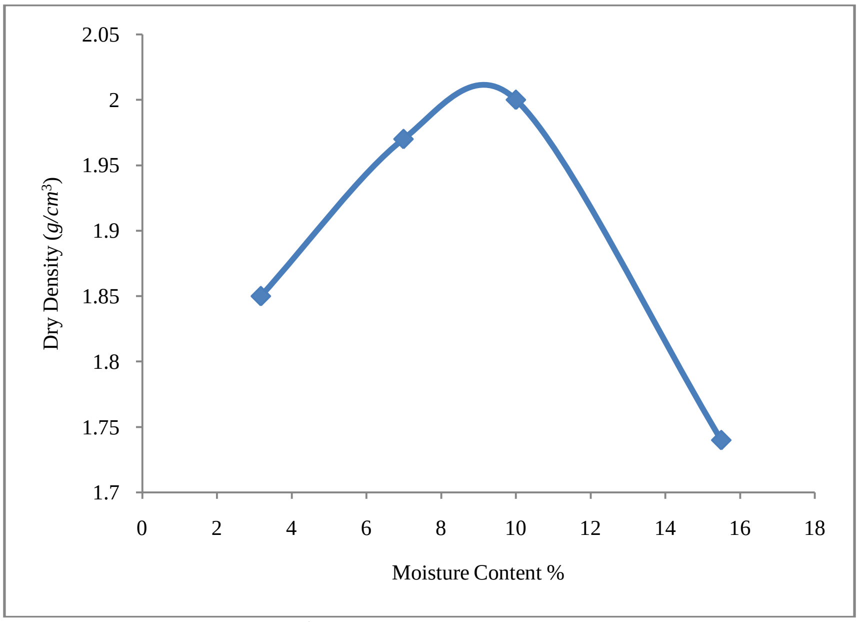

Figure 4: Graph of Dry Density vs Moisture Content at Gamboru.

Table 5: Result obtained from Proctor Compaction Test at Shehuri North

M_{AS} %	W_M (g)	W_{MS}(g)	W_S (g)	ρ_B(g/cm^3)	ρ_D(g/cm^3)	CN	W_C (g)	W_{SC} (g)	W_{DC} (g)	W_D (g)	W_W (g)	W %
3	1851	3850	1999	2.06	1.998	E1	11.5	51.8	50.6	39.1	1.20	3.07
6	1851	3900	2049	2.11	1.991	E2	10.7	55.2	52.7	42.0	2.50	5.95
9	1851	3900	2049	2.11	1.932	E3	11.2	67.5	62.8	51.6	4.70	9.11
12	1851	3800	1940	2.00	1.735	E4	10.9	68.8	60.7	52.6	8.10	15.30

Keys: M_{AS} % = moisture edition soil; W_M (*g*) = weight of mold; W_{MS} (*g*) = weight of mold + weight of soil; W_S (*g*) = weight of wet soil; ρ_B (*g/cm*^{3}) = bulk density; ρ_D (*g/cm*^{3}) = dry density; CN = container number; W_C (*g*) = weight of container; W_{SC} (*g*) = weight of wet soil + container; W_{DC} (*g*) = weight of dry soil + container; W_D (*g*) = wet of dry soil; W_W (*g*) = weight of water; W % = moisture content.

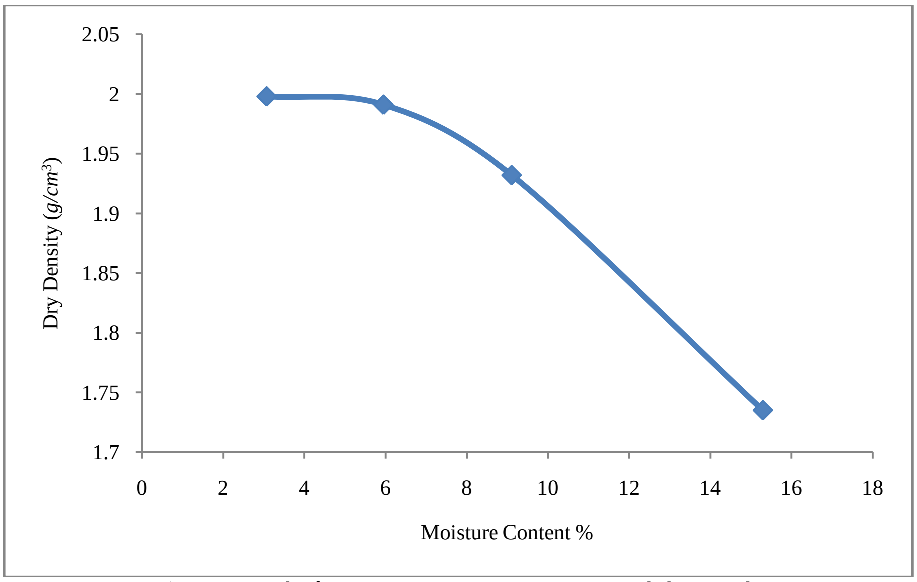

Figure 5: Graph of Dry Density vs Moisture Content at Shehuri North.

Table 6: Result obtained from Proctor Compaction Test at Gwange

M_{AS}%	W_M(g)	W_{MS}(g)	W_S (g)	ρ_B(g/cm^3)	ρ_D(g/cm^3)	CN	W_C (g)	W_{SC}(g)	W_{DC}(g)	W_D(g)	W_W(g)	W %
3	1851	3800	1949	2.01	1.94	F1	10.8	62.5	60.7	49.9	1.8	3.60
6	1851	3900	2049	2.11	1.98	F2	11.5	67.0	63.7	52.2	3.3	6.32
9	1851	4500	2649	2.73	2.49	F3	10.6	70.5	65.2	54.6	5.3	9.70
12	1851	3900	2049	2.11	1.87	F4	10.9	76.9	69.4	58.5	7.5	12.82

Keys: M_{AS} % = moisture edition soil; W_M (*g*) = weight of mold; W_{MS} (*g*) = weight of mold + weight of soil; W_S (*g*) = weight of wet soil; ρ_B (*g/cm*^{3}) = bulk density; ρ_D (*g/cm*^{3}) = dry density; CN = container number; W_C (*g*) = weight of container; W_{SC} (*g*) = weight of wet soil + container; W_{DC} (*g*) = weight of dry soil + container; W_D (*g*) = wet of dry soil; W_W (*g*) = weight of water; W % = moisture content.

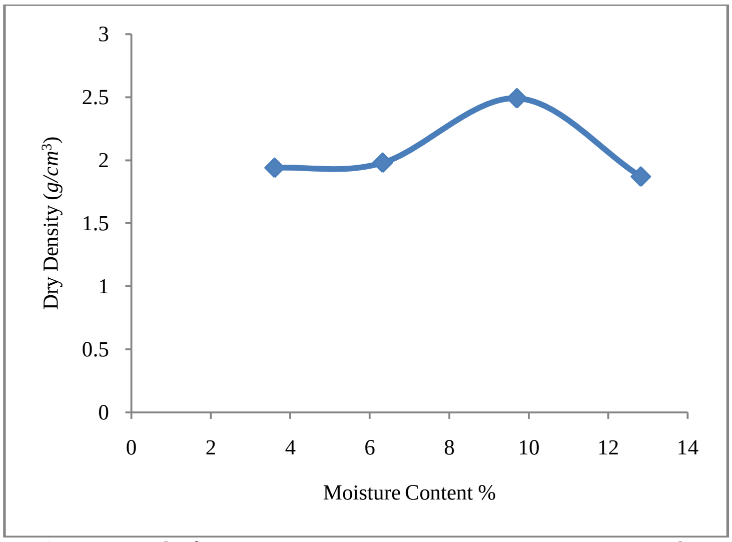

Figure 6: Graph of Dry Density vs Moisture Content at Gwange Layin Tanki.

Table 7: Result obtained from Proctor Compaction Test at Bulabulin

M_{AS}%	W_M(g)	W_{MS}(g)	W_S(g)	ρ_B(g/cm^3)	ρ_D(g/cm^3)	CN	W_C(g)	W_{SC}(g)	W_{DC}(g)	W_D(g)	W_W(g)	W %
3	1851	3800	3750	1.96	1.911	G1	11.0	47.5	46.6	35.6	0.90	2.53
6	1851	3900	3780	1.99	1.890	Q2	11.0	45.9	44.1	33.1	1.80	5.44
9	1851	4500	3850	2.06	1.890	G3	11.3	53.6	50.3	39.0	3.30	8.46
12	1851	3900	3700	1.91	1.670	G4	11.6	79.9	71.3	59.7	8.60	14.40

Keys: M_{AS} % = moisture edition soil; W_M (*g*) = weight of mold; W_{MS} (*g*) = weight of mold + weight of soil; W_S (*g*) = weight of wet soil; ρ_B (*g/cm*^{3}) = bulk density; ρ_D (*g/cm*^{3}) = dry density; CN = container number; W_C (*g*) = weight of container; W_{SC} (*g*) = weight of wet soil + container; W_{DC} (*g*) = weight of dry soil + container; W_D (*g*) = wet of dry soil; W_W (*g*) = weight of water; W % = moisture content.

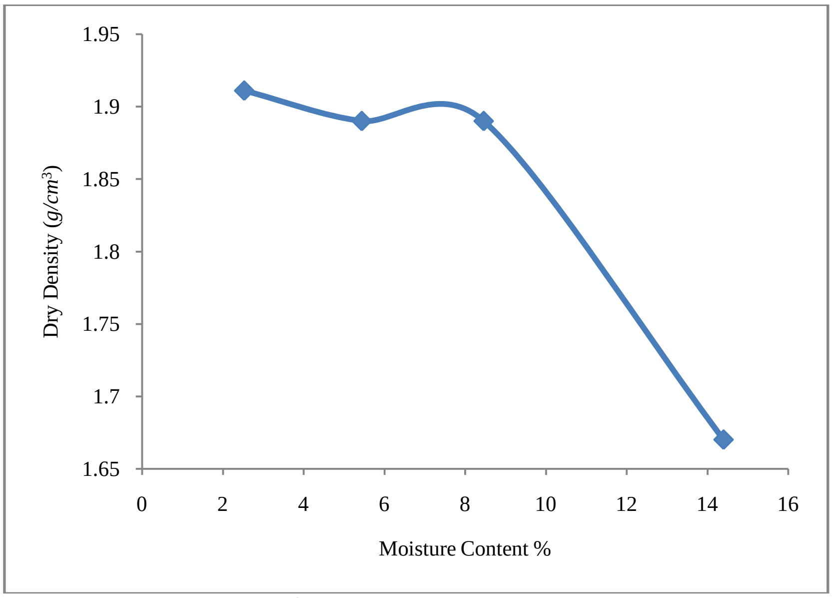

Figure 7: Graph of Dry Density vs Moisture Content at Bulabulin

Table 8: Result obtained from Proctor Compaction Test at Polo Ground

M_{AS} %	W_M (g)	W_{MS} (g)	W_S (g)	ρ_B g/cm^3)	ρ_D(g/cm^3)	CN	W_C (g)	W_{SC}(g)	W_{DC}(g)	W_D (g)	W_W (g)	W %
3	1852	3500	1648	1.65	1.62	H1	11.4	61.6	60.6	49.2	1.00	2.03
6	1852	3550	1698	1.70	1.62	H2	11.4	69.9	67.2	55.8	2.70	4.84
9	1852	3750	1899	1.91	1.77	H3	10..8	67.3	63.2	52.4	4.10	7.82
12	1852	3900	2048	2.06	1.85	H4	11.1	71.1	64.9	53.8	6.20	11.52
15	1852	3600	1748	1.76	1.54	H5	12.2	93.6	83.6	71.4	10.0	14.01

Keys: M_{AS} % = moisture edition soil; W_M (*g*) = weight of mold; W_{MS} (*g*) = weight of mold + weight of soil; W_S (*g*) = weight of wet soil; ρ_B (*g/cm*^{3}) = bulk density; ρ_D (*g/cm*^{3}) = dry density; CN = container number; W_C (*g*) = weight of container; W_{SC} (*g*) = weight of wet soil + container; W_{DC} (*g*) = weight of dry soil + container; W_D (*g*) = wet of dry soil; W_W (*g*) = weight of water; W % = moisture content.

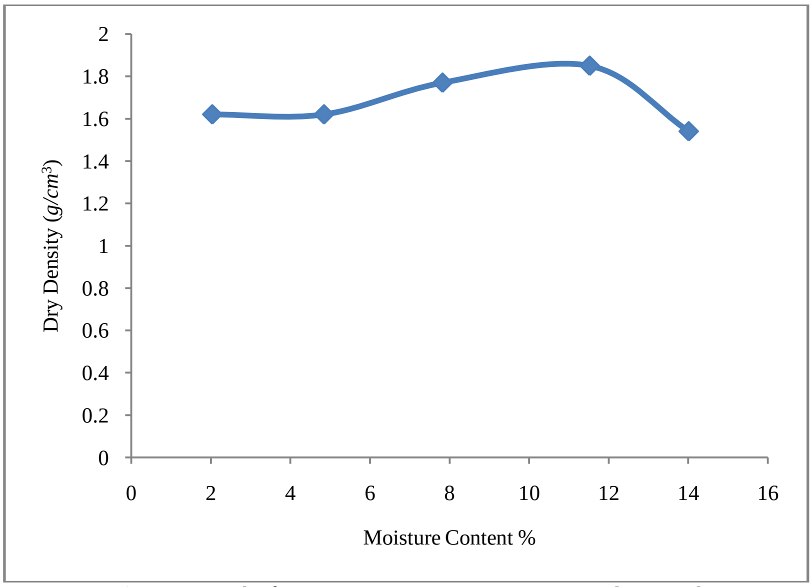

Figure 8: Graph of Dry Density vs Moisture Content at Polo Ground

Table 9: Result obtained from Proctor Compaction Test at National Stadium

M_{AS}%	W_M(g)	W_{MS}(g)	W_S (g)	ρ_B(g/cm^3)	ρ_D(g/cm^3)	CN	W_C(g)	W_{SC}(g)	W_{DC}(g)	W_D (g)	W_W(g)	W %
3	1852	3700	1848	1.86	1.80	I1	11.5	43.5	42.5	31.0	1.00	3.20
6	1852	3800	1948	1.96	1.87	I2	10.8	56.1	54.1	43.3	2.00	4.62
9	1852	3850	1998	2.01	1.81	I3	11.3	71.4	65.4	54.1	6.00	11.1
12	1852	3830	1978	1.99	1.72	I4	12.9	75.4	66.9	54.0	8.50	15.71
15	1852	3750	1898	*1.02*	0.9	I5	11.1	80.4	69.1	58.0	11.3	19.48

Keys: M_{AS} % = moisture edition soil; W_M (*g*) = weight of mold; W_{MS} (*g*) = weight of mold + weight of soil; W_S (*g*) = weight of wet soil; ρ_B (*g/cm*^{3}) = bulk density; ρ_D (*g/cm*^{3}) = dry density; CN = container number; W_C (*g*) = weight of container; W_{SC} (*g*) = weight of wet soil + container; W_{DC} (*g*) = weight of dry soil + container; W_D (*g*) = wet of dry soil; W_W (*g*) = weight of water; W % = moisture content.

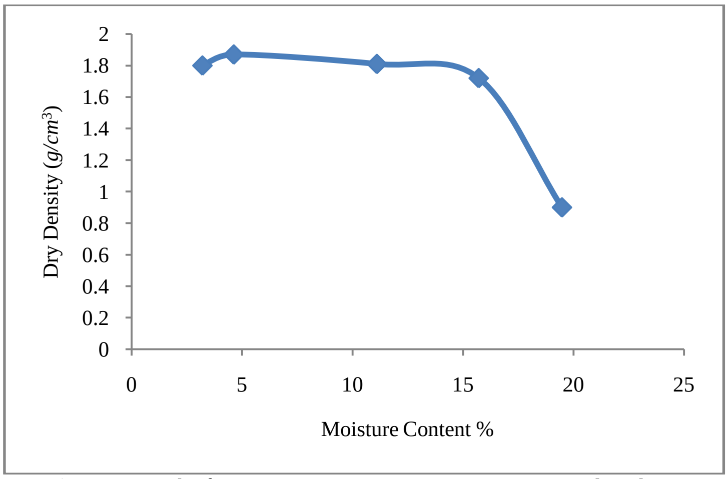

Figure 9: Graph of Dry Density vs Moisture Content at National Stadium.

Table 10: Result obtained from Proctor Compaction Test at Teachers Village

M_{AS} %	W_M (g)	W_{MS} (g)	W_S (g)	ρ_B(g/cm^3)	ρ_D(g/cm^3)	CN	W_C (g)	W_{SC}(g)	W_{DC}(g)	W_D (g)	W_W (g)	W %
3	1852	3500	1648	1.65	1.59	I1	11.7	56.2	54.7	43.0	1.50	3.50
6	1852	3650	1798	1.81	1.67	I2	10.9	66.8	62.4	51.5	4.40	8.50
9	1852	3600	1748	1.76	1.59	I5	11.2	*90.2*	82.4	71.2	7.8	10.9
12	1852	3850	1998	2.00	1.77	I3	10.9	67.0	60.5	49.6	6.50	13.10
15	1852	3851	1999	2.01	1.58	I4	11.6	86.9	70.8	59.2	16.1	27.20

Keys: M_{AS} % = moisture edition soil; W_M (*g*) = weight of mold; W_{MS} (*g*) = weight of mold + weight of soil; W_S (*g*) = weight of wet soil; ρ_B (*g/cm*^{3}) = bulk density; ρ_D (*g/cm*^{3}) = dry density; CN = container number; W_C (*g*) = weight of container; W_{SC} (*g*) = weight of wet soil + container; W_{DC} (*g*) = weight of dry soil + container; W_D (*g*) = wet of dry soil; W_W (*g*) = weight of water; W % = moisture content.

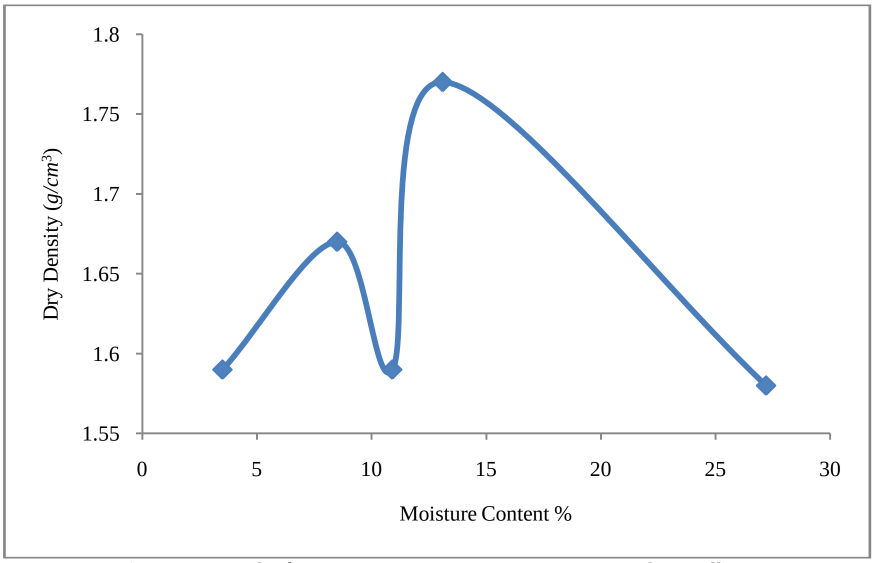

Figure 10: Graph of Dry Density vs Moisture Content at Teachers Village.

IV. Discussion

Figures 1 – 10 are results obtained from Standard Proctor Compaction Test at the locations: Ramat Poly, Bolori Waard, Limanti Ward, Gamboru Ward, Shehuri North, Gwange Ward, Bulabulin Ward, Polo Ground, National Stadium and Teachers Village respectively respectively.The graphs show the optimum moisture content (OMC) and the corresponding maximum dry density (MDD) under each compaction.The values for OMC and MDD are indicated on each graph.

The curves with the peaks shown in Figures 1 – 10 are known as the 'moisture-content dry density curves' or the 'compaction curves'. The state at the peaks are said to be that of 100% compaction at the particular compactive effort. The curves obtained were hyperbolic form, because the points obtained from the tests were smoothly joined.

From the result obtained, the soils at Ramat Poly, Bolori Ward, Limanti Ward, Gamboru Ward, Shehuri North, Gwange Ward, Bulabulin Ward are sand soil. The soil at Polo Ground is clay soil while those at National Stadium and Teachers Village are loam soil. The percentage of the soil seperates are indicated in each Table.

V. Conclusion

Compaction of soil samples have been evaluated and analyzed and the effects of moisture content, particle size, depth, dry density and bulk density were also observed. The variation in compaction may be principally due to range or particle size distribution, bulk density and moisture content of the soils. From the results, it is observed that soil compaction is largely affected by the moisture content of the soils. Variations have been observed in the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) values from all the soils tested under this study.This is because the higher the water content, the greater will be the dry density, because such situation increases the effective inter-particle thermal contact within the soil.

Soil compaction can be used in engineering, agriculture, geotechnical and environmentally related issues. The soil samples have similar engineering and agricultural behaviour, because the growth and development of a crop may be determined to a large extent by soil dry density and bulk density. The practical significance of knowing the soil dry density and bulk density is very important as they are some of the most important factors controlling rates of soil warming and cooling.

It is recommended that a quasi-static compaction technique method be used for the soils at the same location so as to drive comparism between the two methods.

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